(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 283 303 A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 88302393.9

(22) Date of filing: 18.03.88

(51) Int. Cl.4: G 01 M 13/02
G 01 L 1/00

(30) Priority: 20.03.87 JP 67407/87

(43) Date of publication of application:
21.09.88 Bulletin 88/38

(84) Designated Contracting States: DE GB IT NL

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# (54) Method of measuring residual stress in a carrier for a belt for a continuously variable transmission.

(57) An endless metal carrier is bent and treated by heat treatment process to provide residual stress. The carrier is cut, and radius of the cut carrier in free state is compared with a standard radius of a standard carrier having a predetermined residual stress to determine whether the radius coincides with the standard radius.

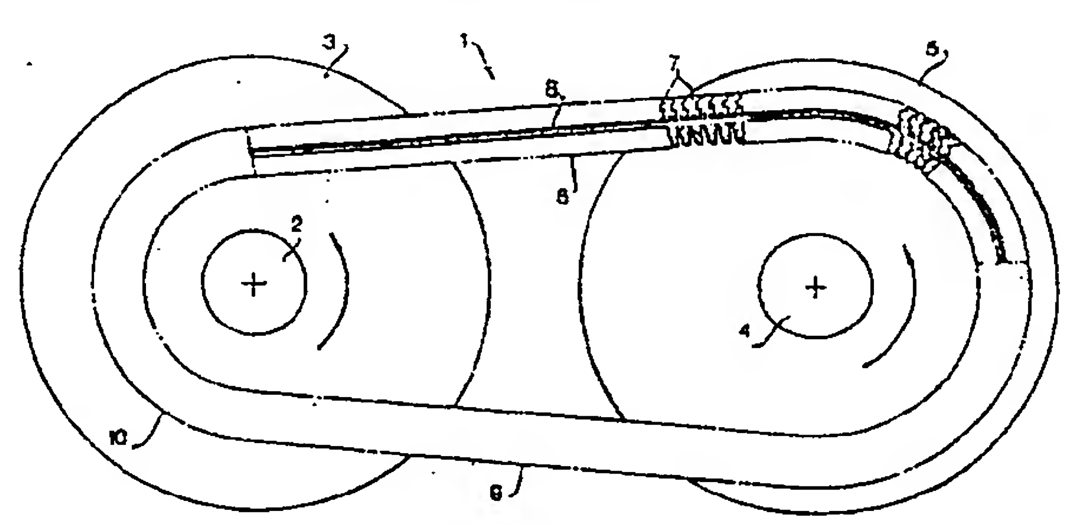

FIG. 1

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D scription

Method of Measuring Residual Stress in a Carrier For A Belt For A Continuously Variable Transmission

The present invention relates to a method for measuring residual stress in a carrier for a belt for a continuously variable belt-drive transmission for a motor vehicle.

A known continuously variable belt-drive transmission comprises an endless belt running over a drive pulley and a driven pulley. Each pulley comprises a movable conical disc which is axially moved by a fluid operated servo device so as to vary the running diameter of the belt on the pulleys in dependence on driving conditions.

The belt comprises a pair of endless carriers and a plurality of metal elements arranged side-by-side on the endless carriers, the carriers engaging in opposed slits of each element. Each carrier comprises a plurality of laminated metal strips.

The carriers are repeatedly bent and straightened as they pass around the pulleys and the straight running sides, so that stresses are produced in the carriers. If the stress exceeds a fatigue limit, the belt may break down by repeated stress. Thus, the service life of the belt becomes short. Japanese Patent Laid Open No. 53-42172 discloses an endless metal carrier which is preliminarily bent to provide a residual stress (internal stress) in the carrier so that a maximum stress which is produced in the carrier during the operation may be below the fatigue limit. Accordingly, strength against repeated bending and straightening is improved.

However, the residual stress given in the carriers is not always constant. Accordingly, dependent on the residual stress the maximum stress may exceed the fatigue limit. Thus, the strength of the belt can not be sufficiently improved. Additionally, it is difficult to accurately measure the residual stress given in the carrier.

The present invention seeks to provide a method of measuring residual stress in metal carrier which may easily measure the residual stress provided in manufacturing thereof.

According to one aspect of the invention, there is provided a method of measuring residual stress in a carrier of a belt for a continuously variable transmission, comprising: bending an endless metal carrier to provide residual stress; heat treating the bent carrier; cutting the heat treated carrier; measuring the radius of a portion of the cut carrier; comparing the measured radius with a predetermined radius, which provides a predetermined residue stress, determining whether the measured radius is within a predetermined range.

According to another aspect of the present invention, there is provided a method of measuring residual stress in a carrier of a belt for continuously variable transmission, comprising bending an endless metal carrier, treating a heat treatment of the bent carrier, cutting the hardened carrier, measuring radius of the cut carrier at a portion, comparing the measured radius with a standard radius of a standard carrier which has a predetermined residual stress, determining whether the measured radius coincides with the standard radius.

Preferably , the predetermined residual stress is such that sum of moments of the residual stress in the carrier becomes zero at a posture where the outer surface maximum stress and an inner surface maximum stress of the carrier equal each other.

A preferred embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

Figure 1 is an elevational view of a belt device;

Figure 2 is a schematic cross section of the belt device of Figure 1;

Figure 3 is an elevational view of an element and carriers of a belt;

Figure 4 is a diagram showing endless metal carriers in which residual stresses having different values are provided;

Figure 5 is an enlarged view of a part of a belt and pulley device; and

Figure 6 is a graph showing a relationship between maximum stresses and radius of the arc of the carrier.

Referring to Figures 1 to 3, a $CO_F$ belt device 1 in which a belt of the present embodiment is shown has an input shaft 2 and an output shaft 4 provided in parallel with the input shaft 2. A drive pulley 3 and a driven pulley 5 are mounted on shafts 2 and 4 respectively. A fixed conical disc 3a of the drive pulley 3 is integral with input shaft 2 and an axially movable conical disc 3b is axially slidably mounted on the input shaft 2. A conical face of the fixed conical disc 3a confronts a conical face of the movable conical disc 3b thereby forming a groove there-between.

A fixed conical disc 5a of the driven pulley 5 is formed on the output shaft 4 opposite a movable conical disc 5b. Conical faces of the respective discs 5a and 5b form a groove. A belt 6 engages the drive pulley 3 and the driven pulley 5.

The belt 6 comprises a pair of endless metal carriers 8 and a plurality of V-shaped metal elements 7 adjacently arranged along the carriers. Each element 7 has a horizontal slit 7b at each side wherein a respective metal carrier 8 is inserted.

The carrier 8 comprises laminated layers of flexible thin metal strips 8a, 8b, 8c..... Both sides of lower portion of each element 7 are inclined to form inclinations 7a so as to frictionally engage with the conical faces of discs 3a, 3b, 5a and 5b as shown in Fig. 3.

The engine power is transmitted from the input shaft 2 to the output shaft 4 through the drive pulley 3, belt 6 and driven pulley 5. As the movable conical discs 3b and 5b are axially moved along the shafts 2 and 4, the transmission ratio is continuously changed.

The belt 6 is repeatedly bent as it passes arcuated portions 10 along the pulleys and straightened at straight running sides 9 between the pulleys. Each carrier 8 is preliminarily bent to have a predeter-

mined residual stress so as to be able to cope with such bending and straightening.

Fig. 4 shows carriers 8 each of which is cut at a portion. Each carrier forms an arc having a certain curvature where the sum of the moments of the residual stresses becomes zero. A radius $R_O$ of the arc varies as shown by chained lines 8′ and 8″ in dependence on the residual stress in the carrier 8.

A maximum stress σinmax produced in the inner surface of the carrier and a maximum stress σoutmax produced in the outer surface of the carrier can be represented as follows:

$\sigma inmax = E \times h/(2R_O - h)$ ......(1)

$\sigma outmax = E \times h \times (R_O - R_M)/2R_O \times R_M$ ......(2)

wherein $R_M$ is a minimum pitch radius of the carrier 8 running over the pulleys as shown in Fig. 5, h is a thickness of the carrier 8 and E is a Young's modulus.

Since the thickness h and the minimum pitch radius $R_M$ are constant in a specific class of a belt drive transmission, the maximum stresses σinmax and σoutmax change dependent on the radius $R_O$ which is dependent on the residual stress. Fig. 6 shows a relationship between the radius $R_O$ and maximum stresses σinmax and σoutmax obtained by the equations (1) and (2), respectively. A bold line M in the graph indicates maximum stress produced in the carrier 8 as a whole.

As shown in the graph, when the radius $R_O$ is small, the maximum stress σinmax of the inner surface of the carrier 8 increases at the straight running sides 9 in the course of the belt 6. When the radius $R_O$ is large, the maximum stress of the outer surface of the carrier 8 increases at the arcuate portions 10. During the running of the belt, when the maximum stress acting on the carrier 8 increases, the strength of the carrier against the repeated bending stress decreases. Thus, in the described instances, the carrier 8 cracks either from the inner surface or from the outer surface as a result of fatigue.

On the other hand, the maximum stress in the carrier 8 as a whole becomes minimum when the outer surface maximum stress σoutmax and inner surface maximum stress σinmax are equal with each other at a radius $R_O1$. Accordingly, it is desirable that a residual stress such that the sum of moments of the residual stress in the carrier becomes zero at the radius ($R_O1$), where the lines indicating maximum stresses of the outer and inner surfaces intersect each other, is provided in the carrier. Thus, the maximum stresses σoutmax and σinmax can be reduced to a minimum value.

The residual stress can be provided in the carrier 8 by proper bending methods. For example, the endless metal carrier 8 is engaged with two tension rollers. A bending roller having a relatively small diameter is pressed against the carrier while it runs by the rotation of the tension rollers. Thereafter, the metal carrier is treated by heat treatment process including a solution treatment and ageing. However, it is difficult to produce a predetermined residual stress in a carrier in manufacturing thereof, and difficult to measure the residual stress in the carrier.

In accordance with the present embodiment, a sample of carrier selected from products is cut at a portion, in order to measure the residual stress. The cut carrier, when left free on a planar surface, forms an arc having a radius, for example a radius R as shown in Fig. 4, in dependence on the residual stress. The radius R is measured and compared with a standard radius $R_O$ of the carrier having a predetermined residual stress. If the difference between the radii exceeds a predetermined range, the previous standard magnitude of bending the carrier or heat treatment is adjusted in accordance with the difference. In manufacturing after the measurement, subsequent carriers are bent in accordance with the standard bending magnitude. Thus, a carrier having the predetermined residual stress can be manufactured. The residual stress can also be easily confirmed in the same manner at an inspection during the manufacture of the carrier.

From the foregoing, it will be understood that the present invention provides a method of measuring residual stress in a carrier which can easily measure residual stress.

While the presently preferred embodiment of the present invention has been shown and described, it is to be understood that this disclosure is for the purpose of illustration and that various changes and modifications may be made without departing from the spirit and scope of the invention as set forth in the appended claims.

## Claims

1. A method of measuring residual stress in a carrier for a belt for a continuously variable transmission, comprising: bending an endless metal carrier to provide residual stress; heat treating the bent carrier; cutting the heat treated carrier; measuring the radius of a portion of the cut carrier; comparing the measured radius with a predetermined radius, which provides a predetermined residual stress; and determining whether the measured radius is within a predetermined range.

2. A method of measuring residual stress in a carrier for a belt for a continuously variable transmission, comprising; bending an endless metal carrier at a predetermined radius to provide a predetermined residual stress; treating heat treatment for the bent carrier; cutting the hardened carrier; measuring radius of the cut carrier at a portion; comparing the measured radius with the predetermined radius, determining whether the measured radius is within a predetermined range.

3. A method as claimed in claim 1 or 2, wherein the predetermined residual stress is such that sum of moments of the residual stress in the carrier b comes zero at a posture where the outer surface maximum stress and the inner surface maximum stress of the carrier equal each other.

4. A method as claimed in claim 3, wherein the posture has an arcuate form.

5. A method as claimed in claim 1, wherein the carrier is initially bent by a standard bending magnitude.

6. A method of measuring residual stress in a carrier for a belt for a continuously variable transmission, comprising: bending an endless metal carrier to provide residual stress; cutting the carrier; measuring the radius of a portion of the cut carrier; and comparing the measured radius with a predetermined radius which provides a predetermined residual stress.

7. A method of manufacturing carriers for belts for a continuously variable transmission with an in built residual stress, comprising: bending the endless metal carrier to provide residual stress; selecting a carrier from the residually stressed carriers, cutting the selected carrier; measuring the radius of a portion of the cut selected carrier; comparing the measured radius with a predetermined radius, which provides a predetermined residual stress, and adjusting the bending provide to subsequently prepared carriers when the measured radius is outside a predetermined range.

8. A method of measuring residual stress in a carrier of a belt for continuously variable transmission, comprising bending an endless metal carrier, treating a heat treatment of the bent carrier, cutting the hardened carrier, measuring radius of the cut carrier at a portion, comparing the measured radius with a standard radius of a standard carrier which has a predetermined residual stress, determining whether the measured radius coincides with the standard radius.

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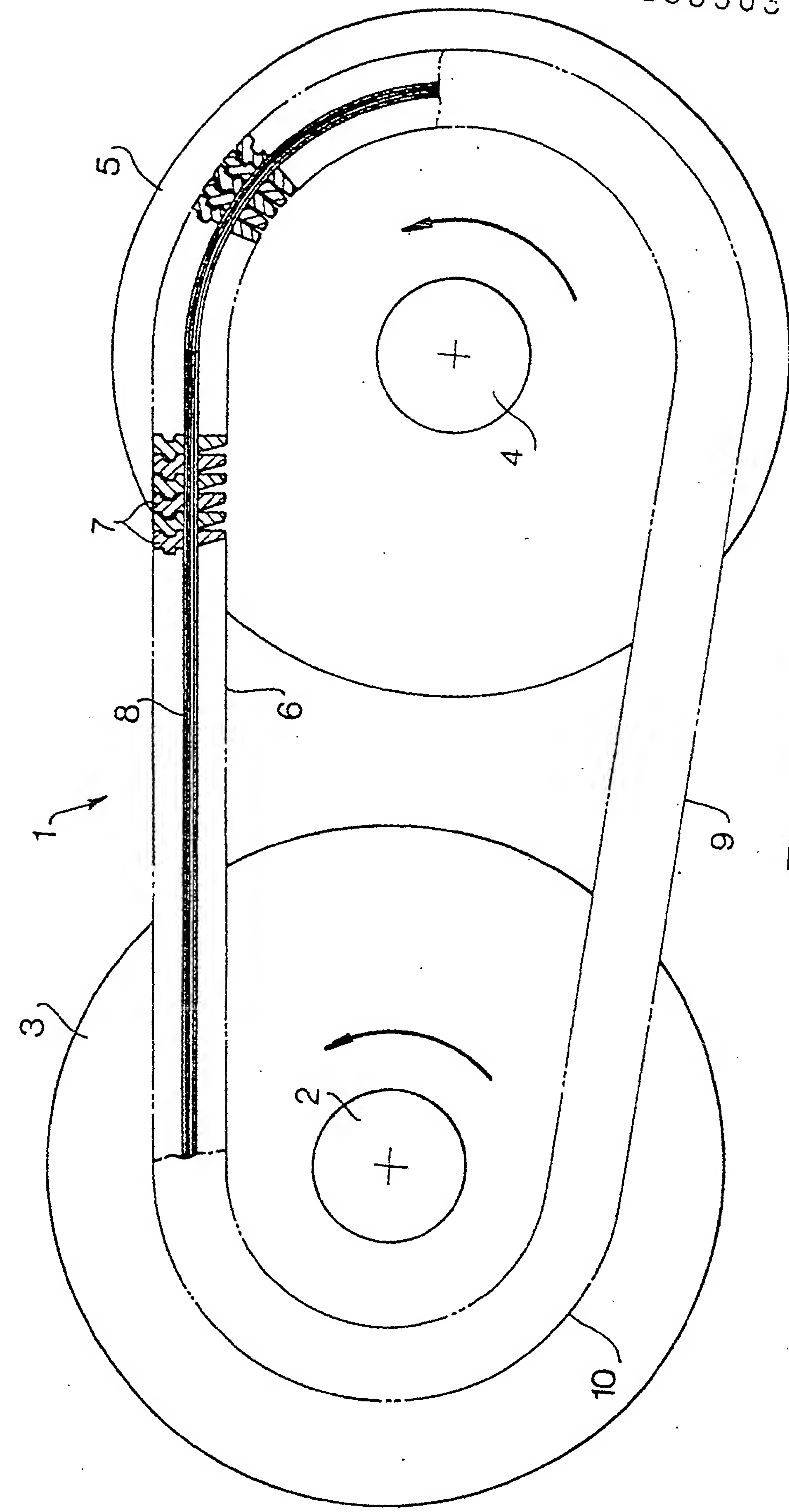


FIG. 1

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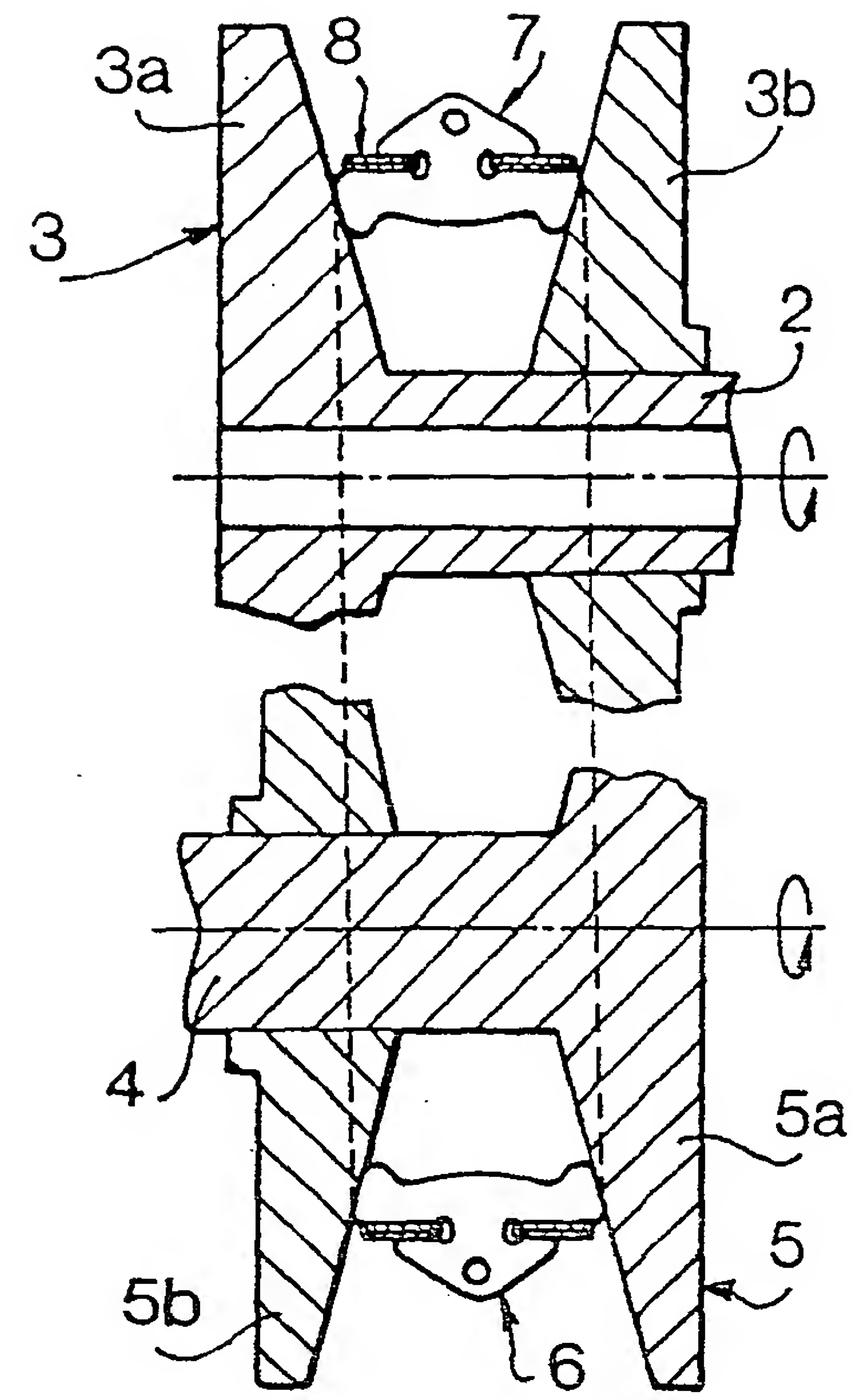



FIG. 2

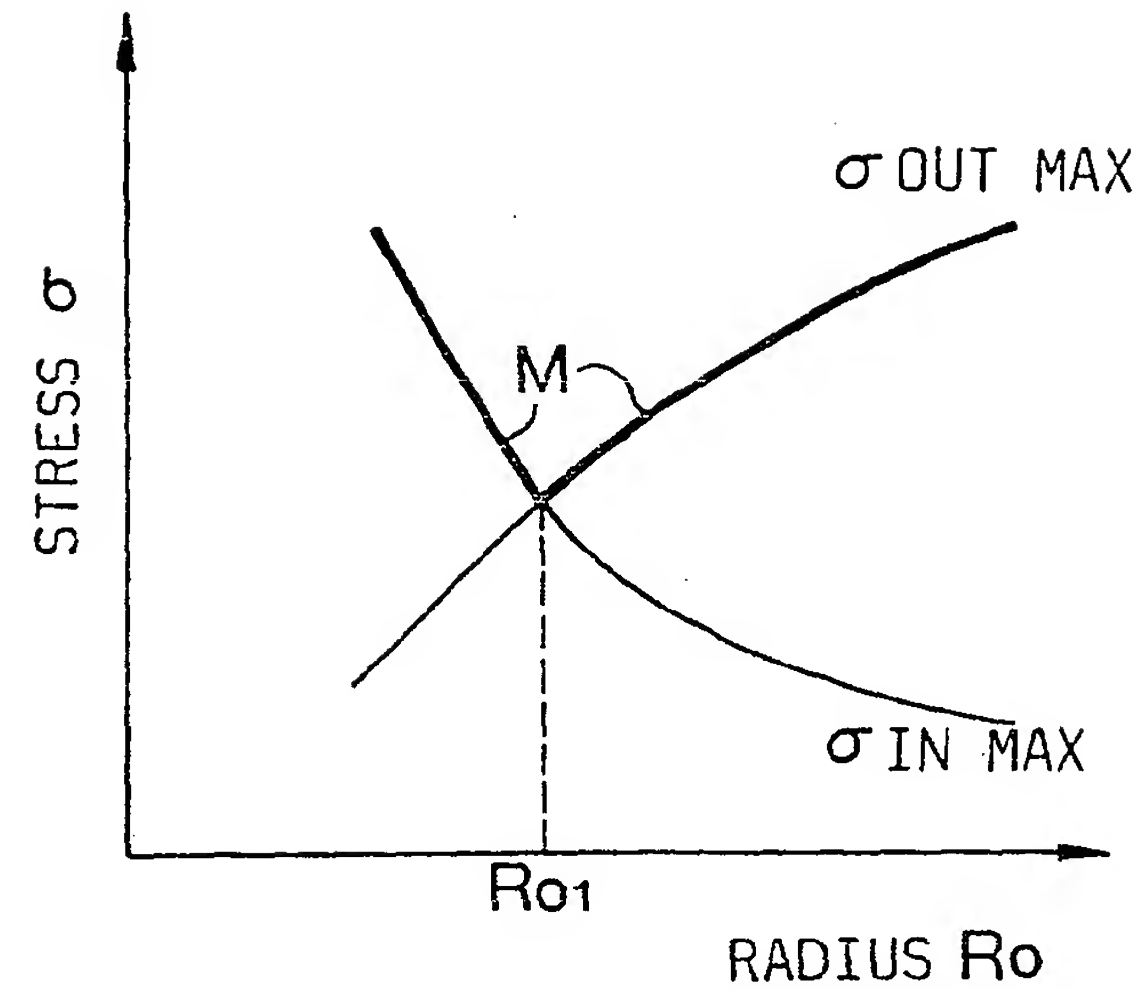
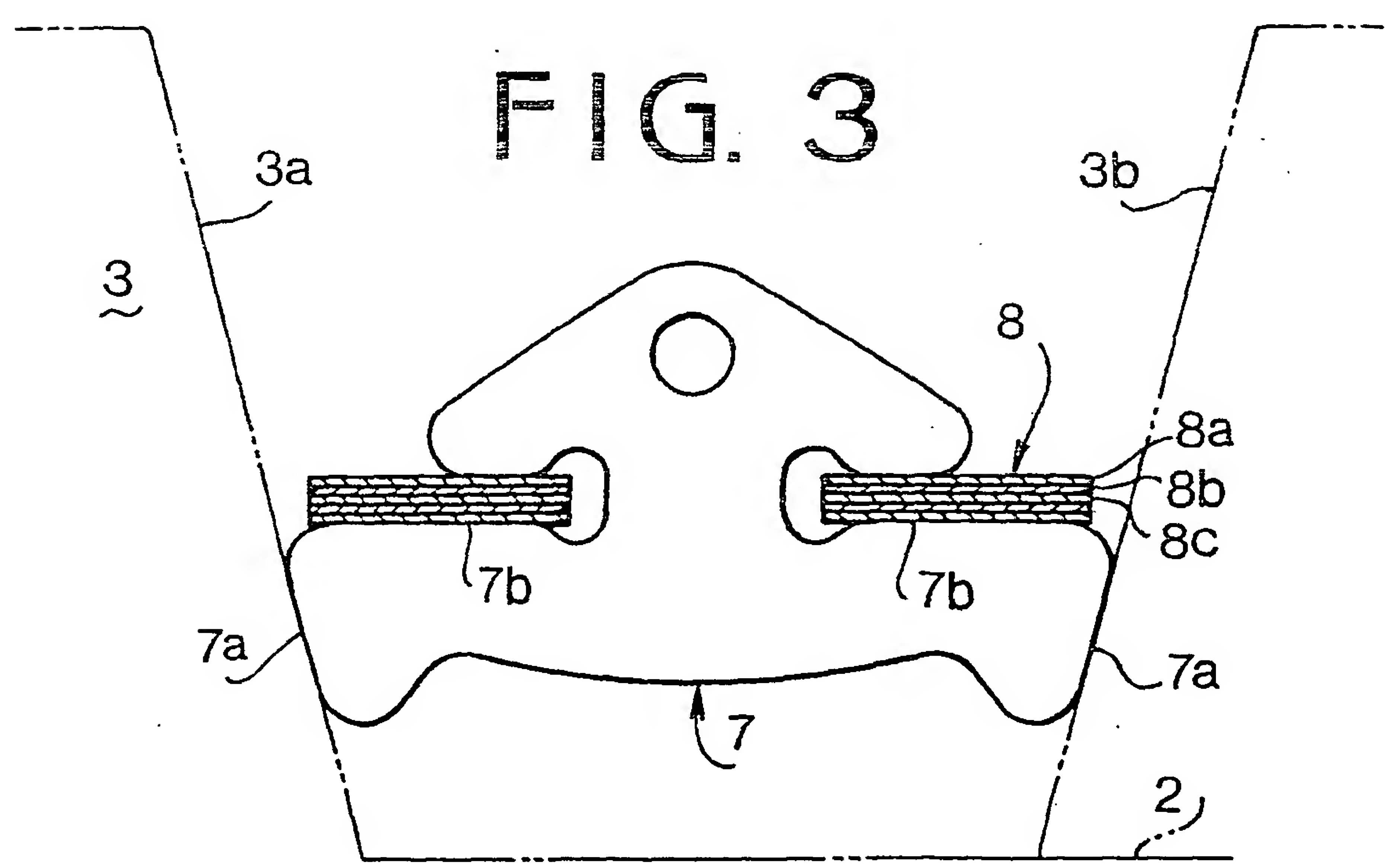



FIG. 6

FIG. 3



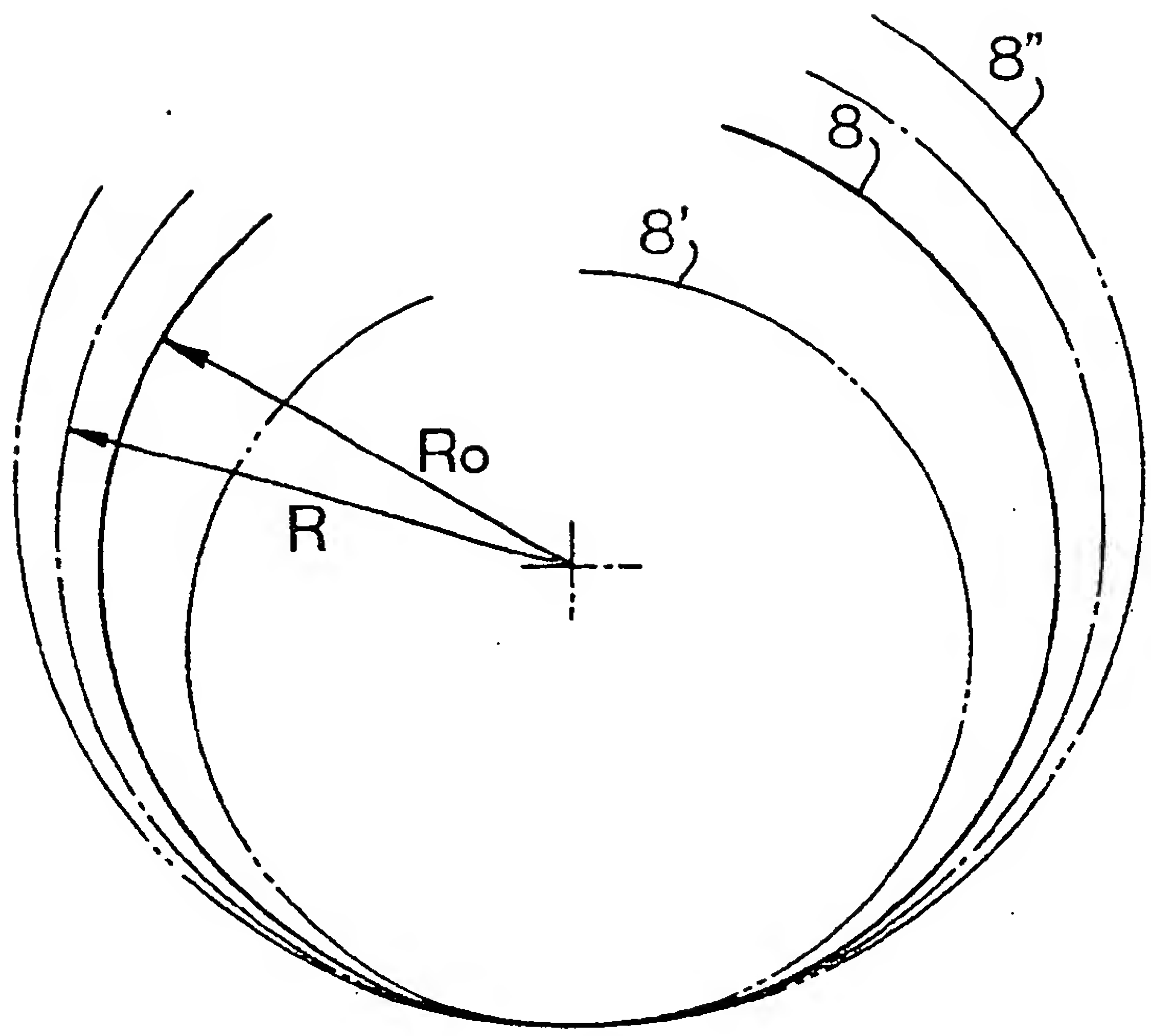



FIG. 4

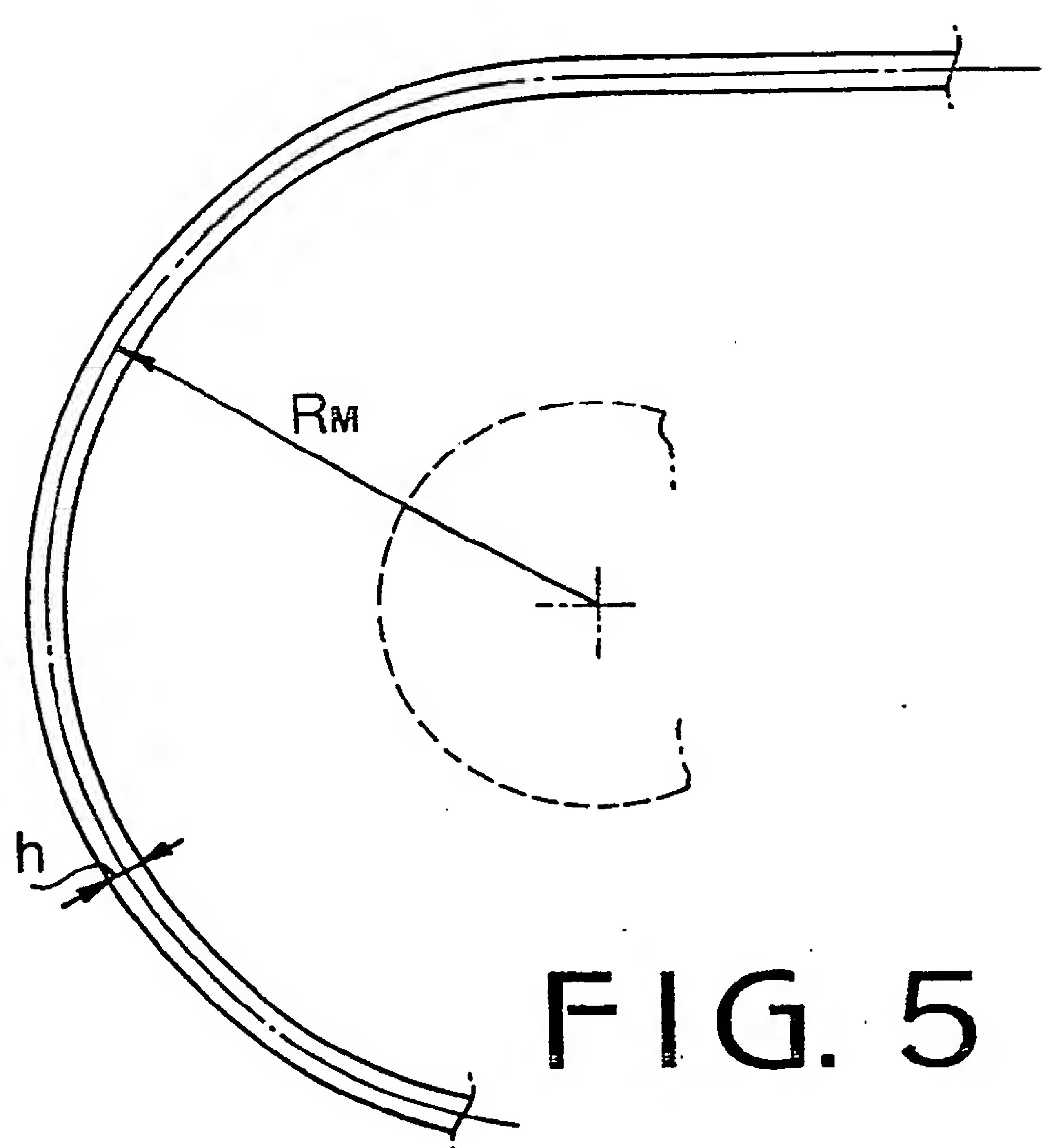



FIG. 5

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(11) Publication number: 0 283 303 A3

# (12) EUROPEAN PATENT APPLICATION

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(22) Date of filing: 18.03.88

(51) Int. Cl.⁴: G01M 13/02 , G01L 1/00

(30) Priority: 20.03.87 JP 67407/87

(43) Date of publication of application: 21.09.88 Bulletin 88/38

(84) Designated Contracting States: DE GB IT NL

(88) Date of deferred publication of the search report: 28.02.90 Bulletin 90/09

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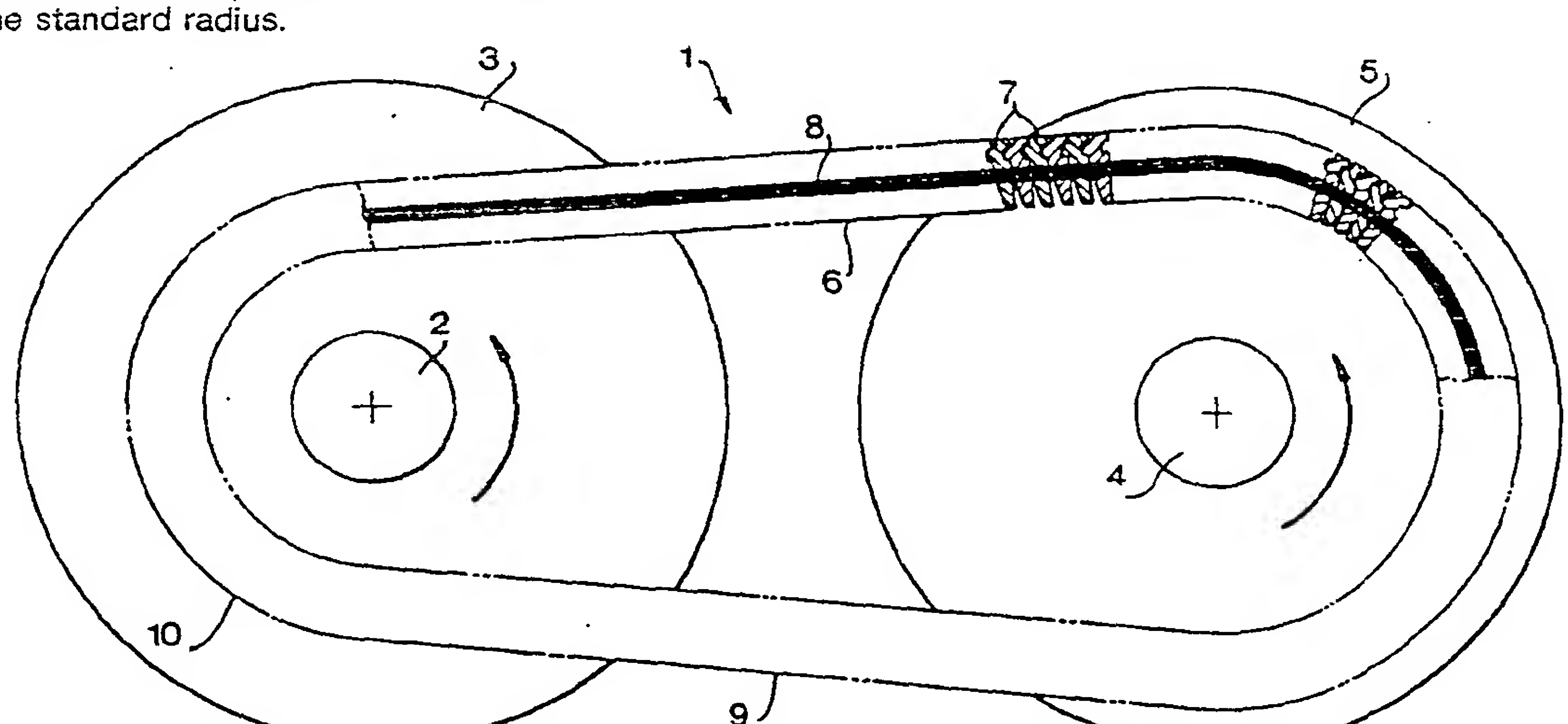


FIG. 1



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# EUROPEAN SEARCH REPORT

Application number

EP 88302393.9

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl 4) |
|---|---|---|---|
| A | A.PEITER "Spannungsmeß-praxis", 1986 FRIEDRICH VIEWEG & SOHN, Braunschweig pages 114-142 * Page 116, lines 7-13; page 131; fig. 9.4 * -- | 1,2,6,7,8 | G 01 M 13/02<br>G 01 L 1/00 |
| D,A | US - A - 4 164 134 (VOLLERS) * Abstract; fig. 5 * -- | 1,2,6,7,8 | |
| A | US - A - 1 383 713 (FORD) ---- | | |
| | | | TECHNICAL FIELDS SEARCHED (Int. Cl 4) |
| | | | G 01 M<br>G 01 L |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
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| VIENNA | 06-12-1989 | NARDAI |

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